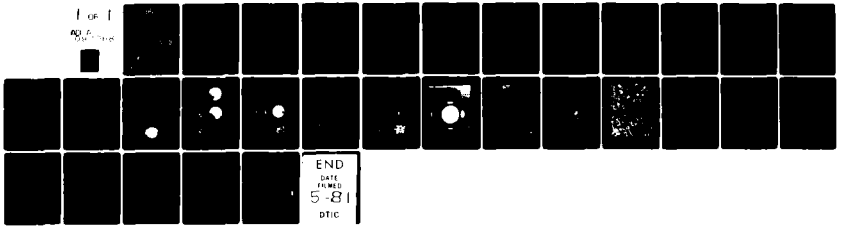
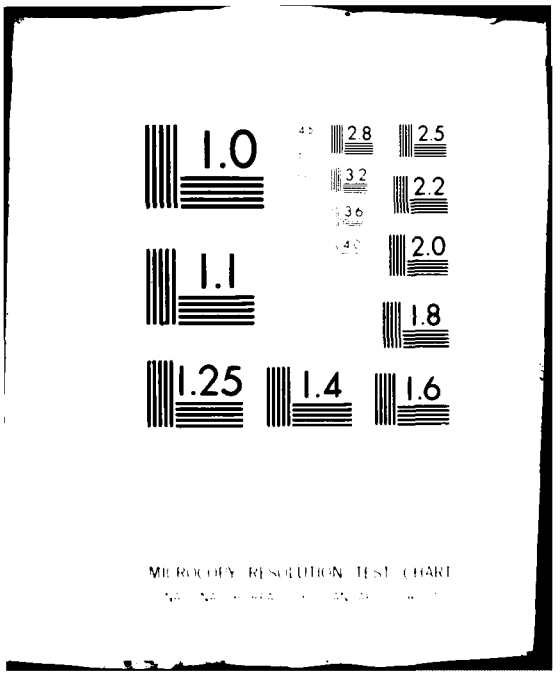
AD-A097 088 NAVAL SURFACE WEAPONS CENTER SILVER SPRING MD F/G 19/1
HOT SPOT INITIATION PATTERNS IN SHOCKED EXPLOSIVES AND PROPELLA--ETC(U)
DEC 80 T P LIDDIARD, M J FRANKEL, C S COFFEY
UNCLASSIFIED NSWC/TR-79-281 NL

1 OF 1
AD A



END
DATE FILMED
5-81
DTIC


1.0
2.8
2.5
3.2
2.2
3.6
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

NSWC TR 79-281

LEVEL II

12

HOT SPOT INITIATION PATTERNS IN SHOCKED EXPLOSIVES AND PROPELLANTS RECORDED BY THERMAL FILM

BY THOMAS P. LIDDIARD MICHAEL J. FRANKEL CHARLES S. COFFEY

RESEARCH AND TECHNOLOGY DEPARTMENT

2 DECEMBER 1980

AD A097088

DTIC ELECTE MAR 3 1 1981 S D F

Approved for public release, distribution unlimited

DTIC FILE COPY

NAVAL SURFACE WEAPONS CENTER

Dahlgren, Virginia 22448 • Silver Spring, Maryland 20910

81 3 31 013

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: NSWC TR-79-281 (14)	2. GOVT ACCESSION NO.: AD-A097 088
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: Hot Spot Initiation Patterns in Shocked Explosives and Propellants Recorded By Thermal Film (6)	5. TYPE OF REPORT & PERIOD COVERED: Technical Report (9) Jan [redacted] - Jun [redacted]79
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): Thomas P. Liddiard, Michael J. Frankel, and Charles S. Coffey (10)	8. CONTRACT OR GRANT NUMBER(s) (17)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Surface Weapons Center, White Oak, Silver Spring, Maryland 20910	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 11228N, HEPS, B0003-SB, 1R13FA
11. CONTROLLING OFFICE NAME AND ADDRESS: Strategic Systems Project Office, Washington, D. C. 20376 (11)	12. REPORT DATE: 2 Dec [redacted]80
	13. NUMBER OF PAGES: 29 (12) 30
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: (16) B00035B	15. SECURITY CLASS. *(of this report)*: Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Explosives
Underwater Shocks
Aquarium Test
Thermal Sensitive Film
Hot Spots
Reaction Thresholds
Propellants

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Recovery of thermally sensitive films from explosives subjected to low level, long duration shocks allows one to obtain in situ records of heating patterns and formation of hot spots. The degree of discoloration in the recovered film corresponds to reaction induced temperatures of the order of several hundred °C. Differing patterns of initiation buildup may be observed in different explosive compositions. The film technique is also seen to be a more sensitive detector of low level reactions than the

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102-LF-014-6601

A

UNCLASSIFIED 44563

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

underwater bulk expansion optical method.

FOREWORD

Recovery of thermally sensitive films from explosives subjected to low level, long duration shocks allows one to obtain in situ records of heating patterns and formation of hot spots. The degree of discoloration in the recovered film corresponds to reaction induced temperatures of the order of several hundred ^{o}C. Differing patterns of initiation buildup may be observed in different explosive compositions. The film technique is also seen to be a more sensitive detector of low level reactions than the underwater bulk expansion optical method.

This work was supported by the High Energy Propellant Safety Program (HEPS) sponsored by the Strategic Systems Project Office of the U. S. Navy and the Exploratory Development Program of the NAVSEA Systems Command (SEA-62R).

J. F. PROCTOR
By direction

Accession For
NTIS CRA&I
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A

CONTENTS

ILLUSTRATIONS

INTRODUCTION

The kinetics of the process by which an input shock may build into a full scale detonation in a reacting explosive is, at present, not well understood. It is generally believed that the reaction initiates at localized regions, forming hot spots. For a sufficiently strong initiating shock, the hot nucleation sites may grow and coalesce in a full scale detonation. Whether an input shock of a given amplitude will provoke a detonation or not depends on the localized temperatures which may be induced and on the spatial distribution of hot spots. A related problem of interest is the response of explosives to low amplitude shocks. While a good deal of effort has been expended to date studying the shock to detonation transition (SDT) in explosives, relatively little information is available on material response to the lower level shocks which may initiate burning without leading to detonation.

Information on hot spot formation, temperature, growth and distribution has been notoriously difficult to come by. Recently Coffey,[1] Jacobs and Elban reported use of a novel technique for obtaining information on temperature and spatial distribution of heating of materials subjected to dynamic loading. Their method involved use of a heat sensitive film placed between the sample and the anvil of an impact machine. A 2.5 kg striker impacted the sample (single crystals of NaCl) from some preset height. The high temperatures generated at crystal slip planes and location of the hot failed material was recorded by a discoloration pattern in the heat sensitive film. Based on the degree of discoloration the temperatures generated were estimated to be of the order of several hundred ^{o}C for a 70 cm. drop height. An earlier version of this experiment was attempted in the 1950's by H. Napadinsky.[2] That effort produced only mixed results due to the inadequate nature of the thermal sensitive film commercially available at that date.

---

1. Coffey, S., Elban W., and Jacobs, S., Proceedings of the 16th JANNAF Combustion Conf., Monterey, CA, 1979.

2. Napadinsky, H., "Development of Methods for Predicting the Response of Explosive Material to Impact," Contract No. AF29 (601)2133, Report No. AFSWCTR-61-8, 1961.

We report here the first use of thermally sensitive film to detect initiation of reaction in explosive materials subjected to a controlled, low pressure, compressional shock wave. This method was found to provide a simple and cheap way of acquiring information on hot spot temperature and distribution and also proved more sensitive in detecting low level reactions than other techniques.

THE THERMALLY SENSITIVE FILM DETECTOR

We have used the same commercially available film employed in Reference 1, the "Heat Sensitive Infrared Film, Type 577" made by the Minnesota Mining and Manufacturing Company. This film is ordinarily used for Vu-graph transparencies and blackens in ordinary use when subjected to temperatures of around 100°C for about 1 sec. With much shorter exposure times characteristic of shock phenomena, the blackening chemical reaction does not have time to go to completion and some intermediate discoloration, ranging from a yellow-green to dark brown, occurs for temperatures on the order of a few hundred °C. This discoloration was shown to be independent of applied pressure (up to about 1.5 GPa) and sensitive only to temperature. A rough calibration showed a threshold temperature of 240°C for an exposure time of 40 μs, which is typical of the shock pulse lengths used in the work reported here. At temperatures of 370°C and above the film turns dark brown. Further details on the calibration may be found in Reference 1.

THE EXPERIMENTAL CONFIGURATION

We have used the thermally sensitive film in conjunction with the underwater aquarium test. The underwater test, illustrated in Figure 1, was designed to produce a long duration (20-40 μs), relatively low amplitude shock (.3 to 3 GPa) in a low friction geometry. A 472 gm spherical donor charge of case pentolite is suspended by a nylon thread harness in the center of a supporting metal rig. The acceptor charges, consisting of 1 inch thick, 2 inch diameter disks were suspended by a mylar tape, glued at the cylindrical surfaces and positioned with the flat surface facing the pentolite donor. The donor acceptor system is placed underwater in the "aquarium". The enhanced confinement of the water reduces the amplitude of rarefactions from the sample surface. The pressure in the water vs. distance from a pentolite donor was recalibrated recently at the Naval Surface Weapons Center. The entering pressure in the sample is then obtained in the usual way from the Hugoniot curves using the techniques described in Rice et. al.[3]

---

3. Rice, M., McQueen, R., and Walsh, J., "Compression of Solids by Strong Shock Waves," Solid State Physics 6 1 (Academic Press, NY) 1958.

In the past,[4] chemical reaction was inferred by observing bulk expansion of the acceptor after being struck by the shock wave emanating from the donor. Observations were made with a Jacobs framing camera and lighting provided by an argon flash bomb. Reference 4 may be consulted for greater experimental detail. With the thermally sensitive film method, the Jacobs camera, argon bomb and associated timing electronics are dispensed with. The acceptor charges are sectioned into two 2 inch diameter by 0.5 inch thick discs and a 2 inch diameter section of film is placed at the front, back and middle of the donor assembly as illustrated in Figure 2. A thin layer of silicone grease was applied at the perimeter of the film sections to improve adherence to the sample. After detonation of the donor, the heat sensitive film is recovered from the rubble and examined for signs of heating.

RESULTS

We have tested the heat sensitive film with a number of different high explosives and high energy propellants as well as with an explosive (PBXN-106) simulant. The results of these tests are reported below.

PRESSED TNT. Figure 3 shows the three film sections from the front, middle and back face, recovered from a pressed TNT acceptor (ρ = 1.62 g/cm^3) subjected to an input pressure pulse of 0.57 GPa. The front disk shows considerable browning over the entire surface area while the middle and back face disks show almost no discoloration at all. The extensive browning of the front face film is evidence of significant chemical release of heat near the surface. As the second film shows no discoloration we believe that the region of intense heat was restricted to a relatively thin layer near the input surface, after which the reaction quenched. At 0.5 GPa no discoloration of the film was observed. It is interesting to note that the threshold for burning as determined by the underwater acceptor expansion method is about 0.8 GPa but jetting had been observed to occur at half this pressure. The thermal film is thus detecting reactions at much lower levels than those detected in Reference 4.

PRESSED PENTOLITE. The results of the tests with pressed pentolite (ρ = 1.66 g/cm^3) are shown in Figure 4. The pattern of reaction growth is quite different than for the TNT. Figure 4a corresponds to an input shock of 0.48 GPa. Little surface browning is evidenced on the first disk while the middle and back surfaces display a singular degree of extensive browning. The reaction buildup has been much more gradual than in the TNT with substantial chemical activity taking place in the middle and sustainment of vigorous reaction levels through the end of the acceptor. The results at 0.45 GPa are

---

4. Liddiard, T., "The Initiation of Burning in High Explosives and Propellants," Proc. of Fourth Int. Symposium on Detonation, 478 (ONR-1965).

shown in Figure 4b. There are brownish discolorations on the first and second film disks while the back disk showed no color change. The reaction level was clearly quenching as the initiating shock amplitude became marginal. The threshold for initiation found by the acceptor expansion method[5] was 0.45 GPa.

PRESSED COMP B. In Figure 5 we display the results for pressed Comp B (ρ = 1.71 g/cm^3) subjected to shocks of 0.48 GPa and 0.56 GPa respectively. At 0.48 GPa (Figure 5a) there are isolated brown spots on the first film with a more extensive browning in the middle while the third film contains only a yellow-green discoloration over half its surface area. The reaction has built up by the coalescence of hot spots and is fairly vigorous in the center but has almost entirely died out by the time it reached the back face. A similar pattern of reaction buildup and subsequent decay is shown in Figure 5b. The input shock was somewhat higher (0.56 GPa vs. 0.48 GPa) and the reaction at the front surface and remaining reaction at the back surface were correspondingly more vigorous. The radial flow pattern is also clearly discernable on the front face film. No underwater expansion threshold for burning data was ever obtained for Comp B.

CAST COMP B. The results obtained with cast Composition B are somewhat disappointing. It was hoped that more could be learned of the build-up in the HE by replacing the center (parallel) film with one that is diagonally oriented, as in Figure 6. The cast material, though, is a poor choice since it is not as uniform as material that has been isostatically pressed. Apparently, during the casting process, a region of lower density can form down the center of the charge. This region would be more sensitive to shock than that near the periphery, thus clouding the interpretation of results. At any rate, acceptors at .56 and .6 GPa showed evidence of mild reaction at the first film. Little reaction reached the half-way point on the diagonal films. At .6 GPa a moderate amount of reaction is indicated on the diagonal film at the end nearest the donor, but the reaction appears to have fallen off sharply after traveling 0.5 inches. The third films at .56 and .6 GPa show no evidence of reaction. No other burning threshold data were measured for cast Comp B.

LX-04-0. LX-04-0 (ρ = 1.86 g/cm^3) is an 85% HMX based explosive composition plus binder. No color changes on the heat sensitive film were observed at shock levels of 0.48 and .6 GPa. The results of tests at .92 and .99 GPa are shown in Figure 7. At .92 GPa the first film showed several brown spots on the periphery with nothing showing up on the other two films. At .99 GPa the first film showed a considerable area of browning. The second film (in this case only two films used) showed considerably less discoloration, indicating a die-out of reaction. The critical pressure for reaction in LX-04-1 using the underwater expansion method is .9 GPa (LX-04-1 and LX-04-0 are chemically identical and have essentially the same threshold of burning as determined by the Modified Gap Test. It is interesting to note that Figure 7a indicates that reaction seems to be initiating at a number of hot spots on the periphery. Examining some of the early acceptor expansion records on LX-04-1, shown in Figure 8, we

note that the face nearest the donor seems to be shearing outwards immediately after the shock has struck. This lateral velocity in LX-04-1 was measured at about 20 m/s. The resulting initiation sites on the periphery suggest that shear mechanisms play a larger role in initiation than previously suspected in these acceptor-donor underwater systems. The 0.99 GPa shock induced considerable browning and some blackening. When the film was examined under a microscope the hot spots associated with the individual HMX particles could be clearly seen (Figure 9). The irregular shapes and occasional "tails" of the blackened regions is evidence of the deformation and flow to which the particles have been subjected. Under close inspection, it is possible to discern patterns of light areas surrounded by hotter darker regions. We believe this is due in part to patterns of localized heating produced during crystal fracture.

PROPELLANTS VRA-23 AND ALTU-16. VRA-23 and ALTU-16 are experimental propellants containing aluminum, HMX and ammonium perchlorate with lunder material. The VRA-23 was subjected to shocks of 0.56 GPa at which a very slight reaction was detected and 0.59 GPa shown in Figure 10a. The reaction threshold as determined by the bulk expansion method was 1.2 GPa.[5] In contrast the ALTU-16 showed vigorous reactions down to 0.4 GPa (Figure 10b). This increased sensitivity to burning at lower shock levels as compared with VRA-23 was confirmed by the acceptor expansion method where the initiation sensitivity curves of VRA-23 and ALTU-16 were shown to cross at 1.7 GPa. This crossing indicated that whereas VRA-23 was easier to detonate than ALTU-16 it was more insensitive to burn at lower levels of shock. The VRA-23 contained some ingredient which attacked the heat sensitive emulsion. Consquently, it was necessary to shoot as soon as possible after the charges were prepared, but a degree of distortion was unavoidable.

PBXN-106 SIMULANT. The simulant is made of polystyrene and glass beads and is fairly rubbery. The sample size was 2.5 inch diameter by 1.5 inches high. When subjected to a 0.4 GPa shock the sample displayed considerable browning indicating locally high temperatures, possibly due to fracture of the glass beads or some other mechanical process. When viewed under a microscope (see Figure 11) a very regular sized crater pattern is observed. This is undoubtedly due to the violent impingement of the glass beads on the film, which leads us to suspect fracture as the source of localized heating (see Figure 12). The simulant subjected to a .25 GPa shock showed no such discoloration.

---

5. Frankel, M., Liddiard, T., and Forbes, J., "Low Level Shock Reaction Thresholds in High Explosives and Propellants," to be published.

CONCLUSIONS

It is clear that the use of heat sensitive film allows one to get a handle on the thorny experimental problem of tracking patterns of reaction buildup in explosive materials. It is also apparent that the film technique is capable of detecting in situ heating at much lower levels than possible with the underwater bulk expansion technique. A number of problems remain, however, before the film technique becomes a more useful quantitative tool. The calibration of temperature vs. exposure times needs additional investigation. It is also possible that some of the heating may be produced by some non-chemical means, such as particle fracture. There is experimental evidence that such processes do occur and will be reported on elsewhere. In some instances, the ingredients in the sample being tested may attack the thermally sensitive emulsions. It would be of interest to study the use of other types of thermally sensitive recording films or materials to see whether the performance or sensitivity might be improved.

We would like to thank Dempsey Gillmore and Bob Baker for their invaluable assistance in running this series of experiments.

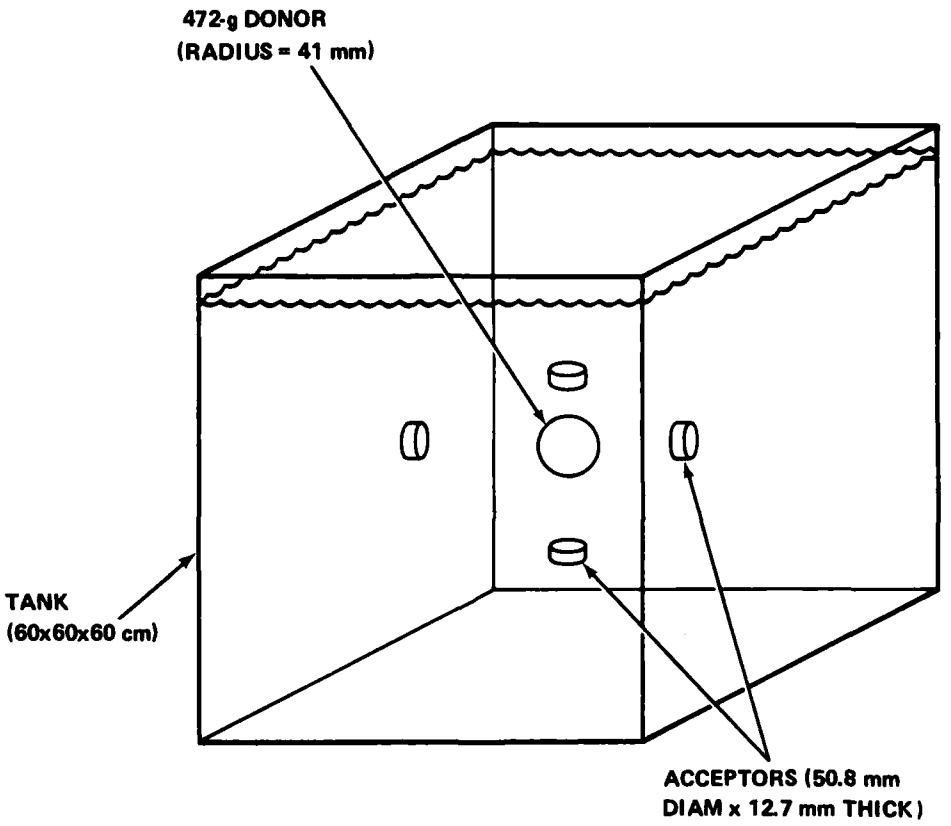


FIGURE 1 THE UNDERWATER AQUARIUM SYSTEM

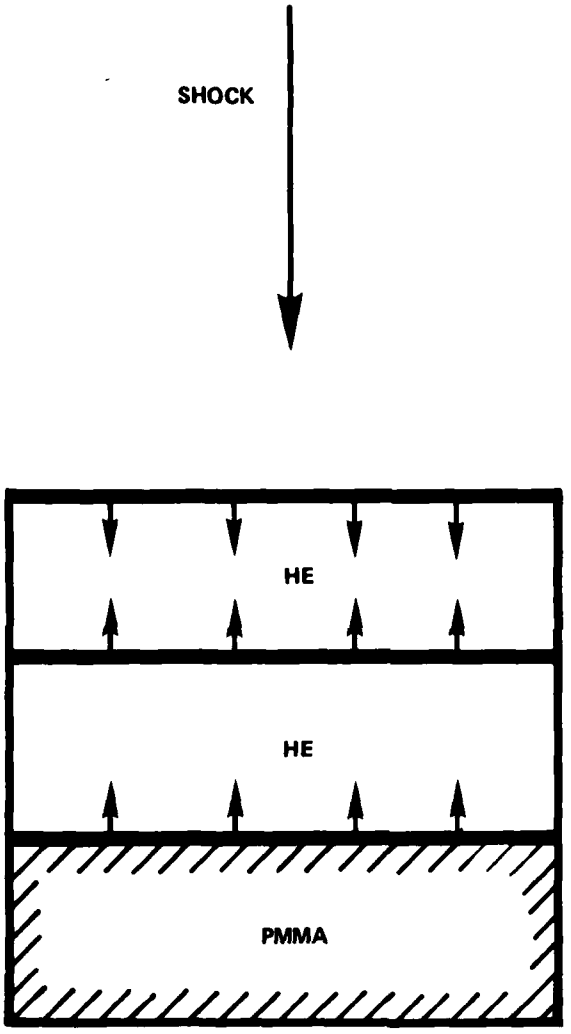


FIGURE 2 ACCEPTOR CHARGE ASSEMBLY. ARROWS INDICATE SIDE OF FILM WITH THERMALLY SENSITIVE EMULSION

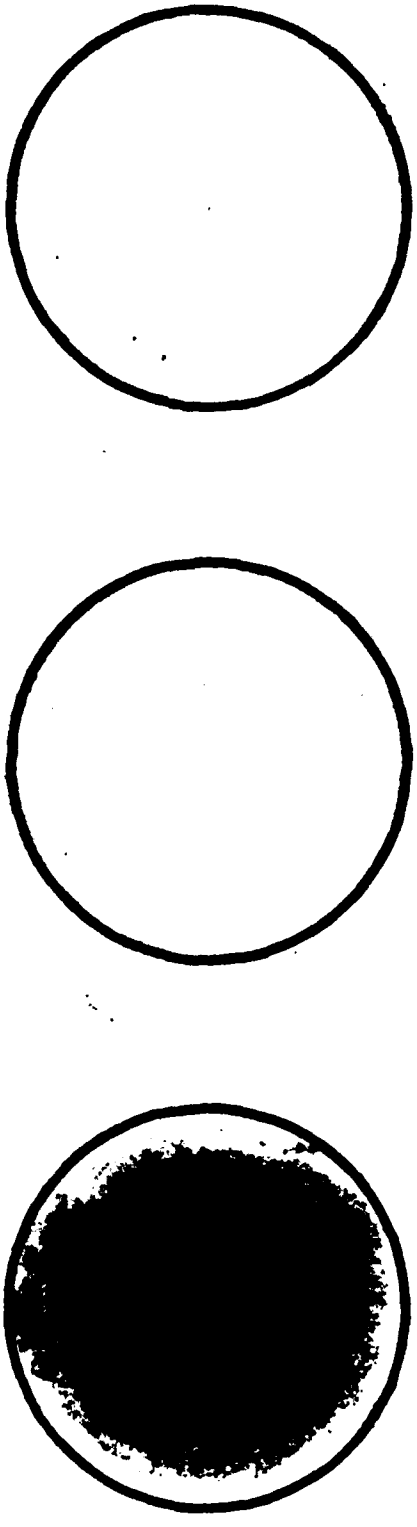


FIGURE 3 FILM RECOVERED FROM PRESSED TNT (P_w = 0.57 GPa)

FIGURE 4 FILM RECOVERED FROM PRESSED PENTOLITE A. P_w = 0.45 GPa, B. P_w = 0.48 GPa

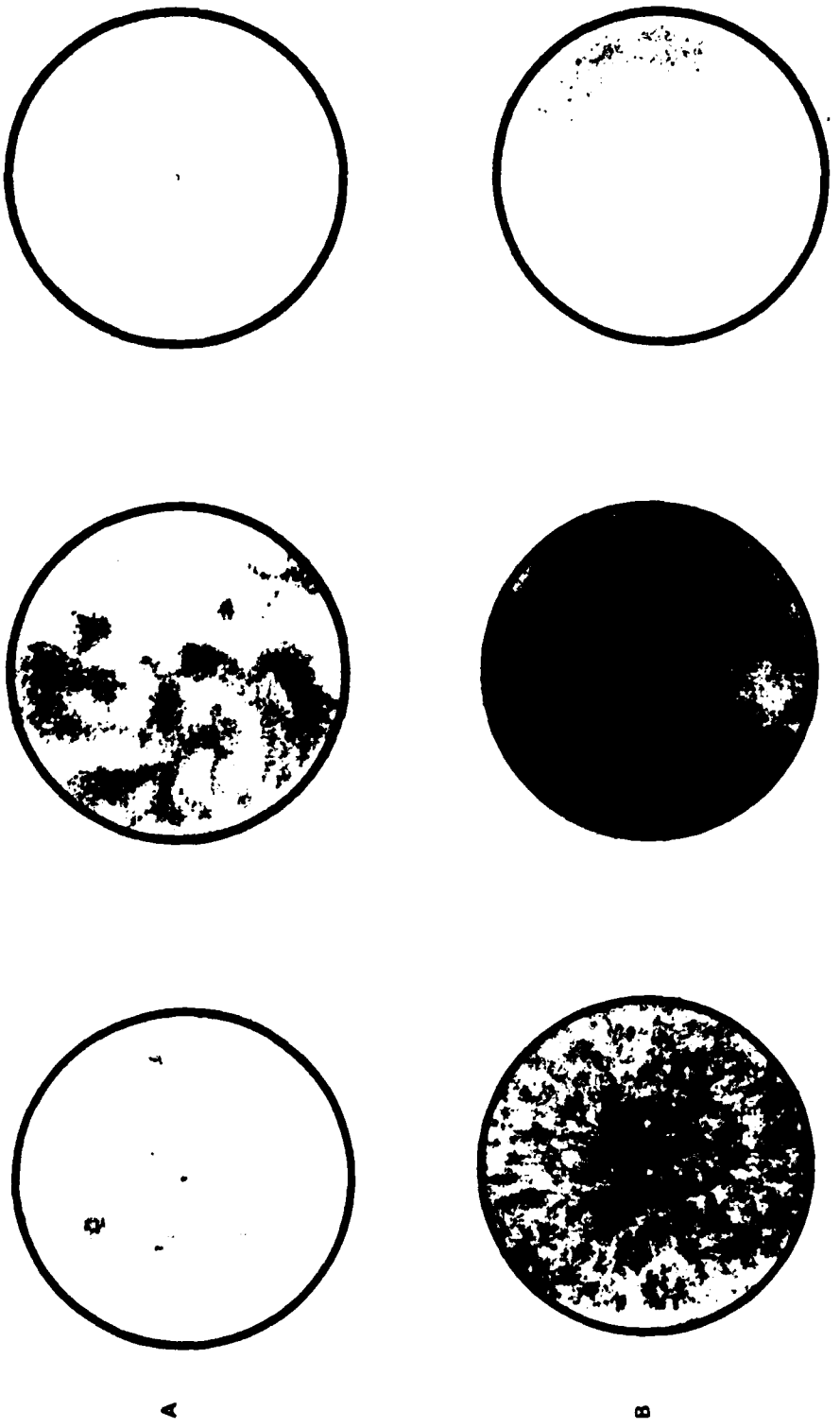


FIGURE 5 FILM RECOVERED FROM PRESSED COMP B A. P_w = 0.48 GPa, B. P_w = 0.56 GPa

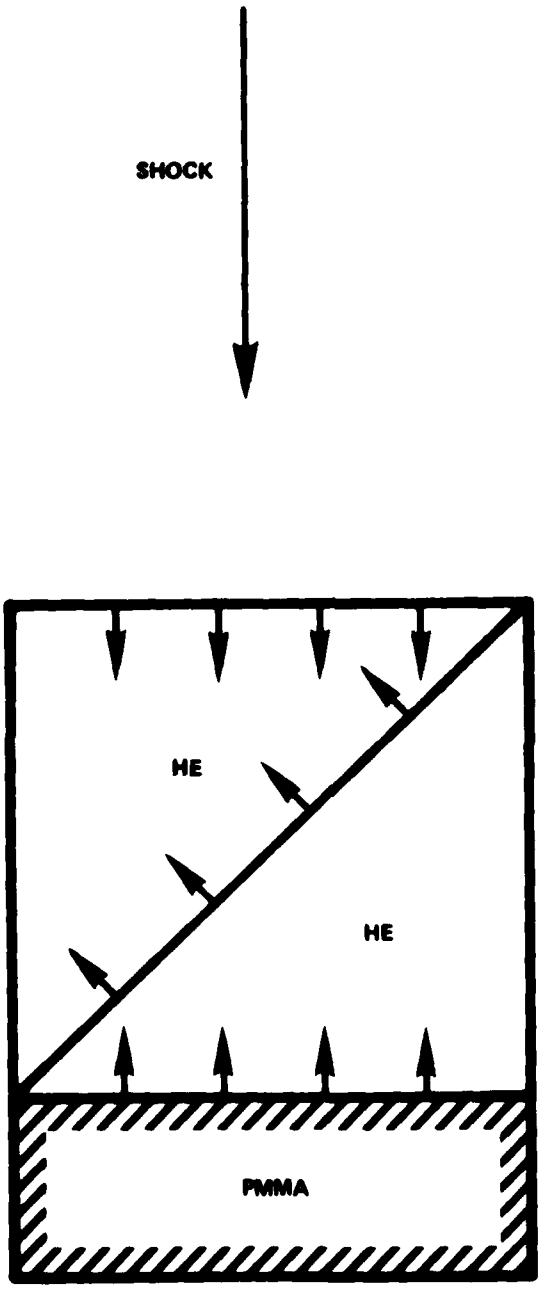


FIGURE 6 ACCEPTOR CHARGE ASSEMBLY WITH DIAGONALLY EMBEDDED THERMAL FILM

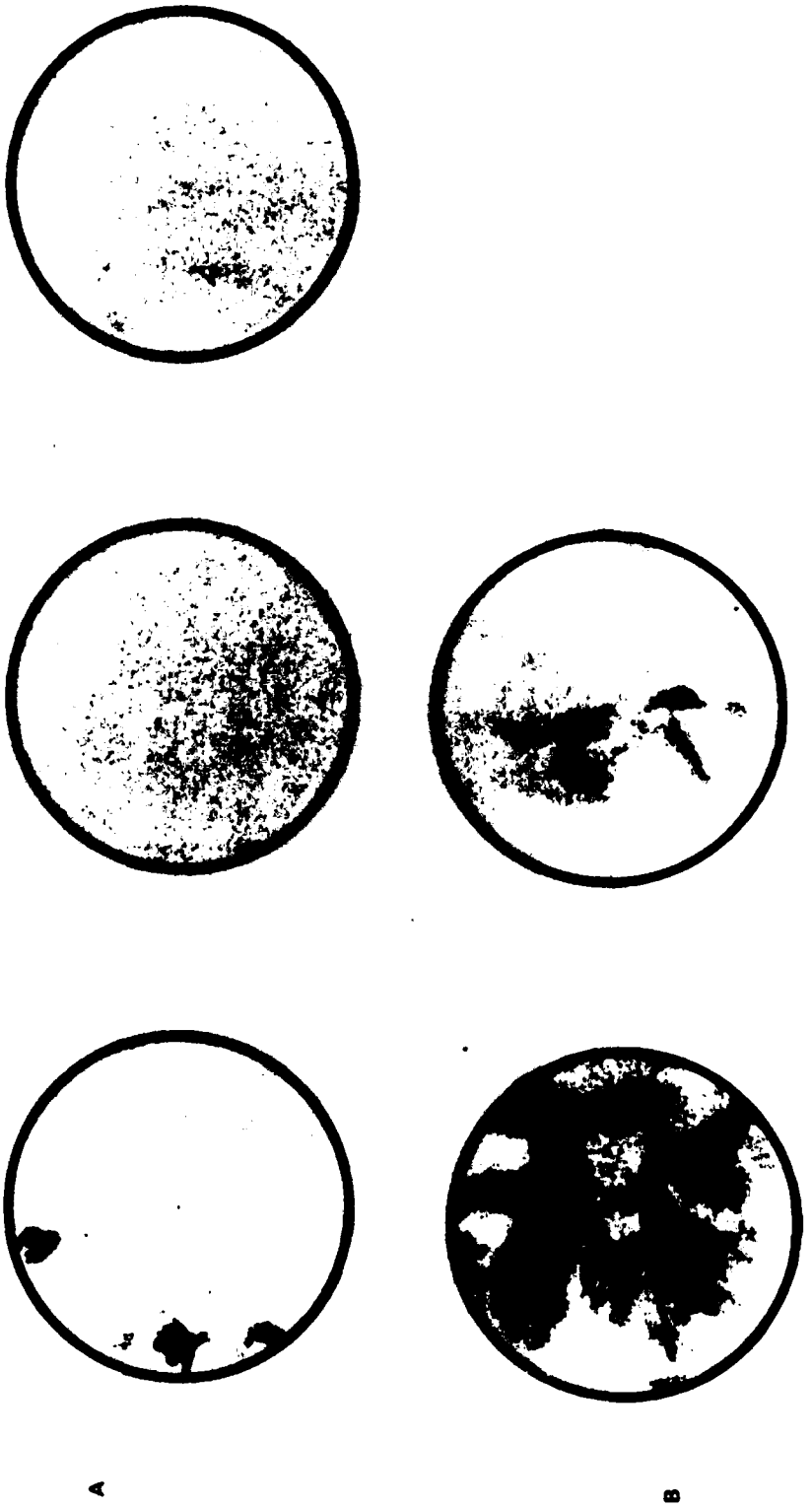


FIGURE 7 FILM RECOVERED FROM LX-04
A. P_w = 0.92 GPa, B. P_w = 0.99 GPa

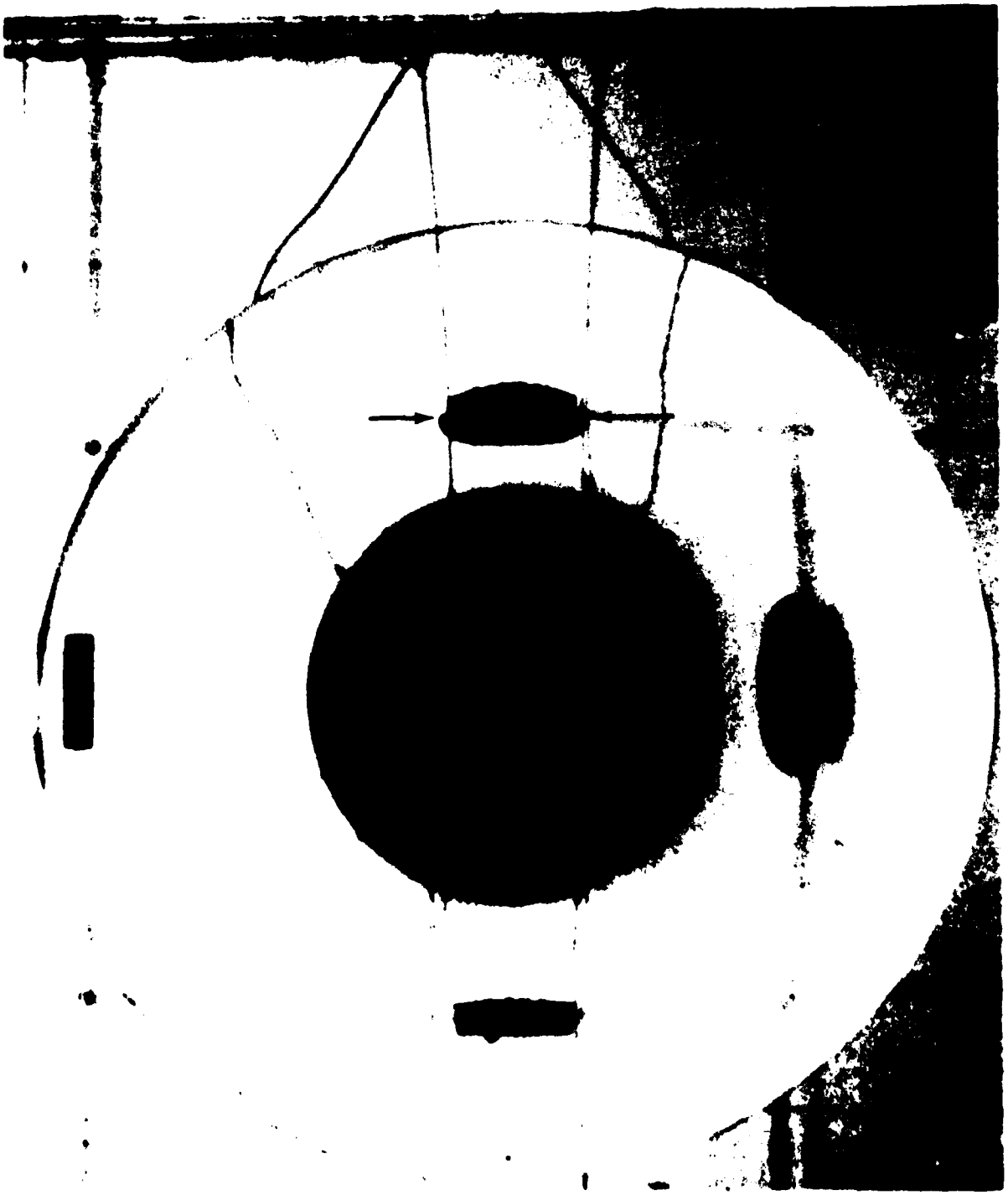


FIGURE 8 UNDERWATER EXPANSION OF LX 04 ACCEPTOR. ARROWS INDICATE LATERAL EXPANSION NEAR SHOCKED SURFACE

FIGURE 9 PHOTOMICROGRAPHIC ENLARGEMENT (120X) SHOWING HEATING PATTERNS PRODUCED ON THERMAL FILM BY HMX PARTICLES

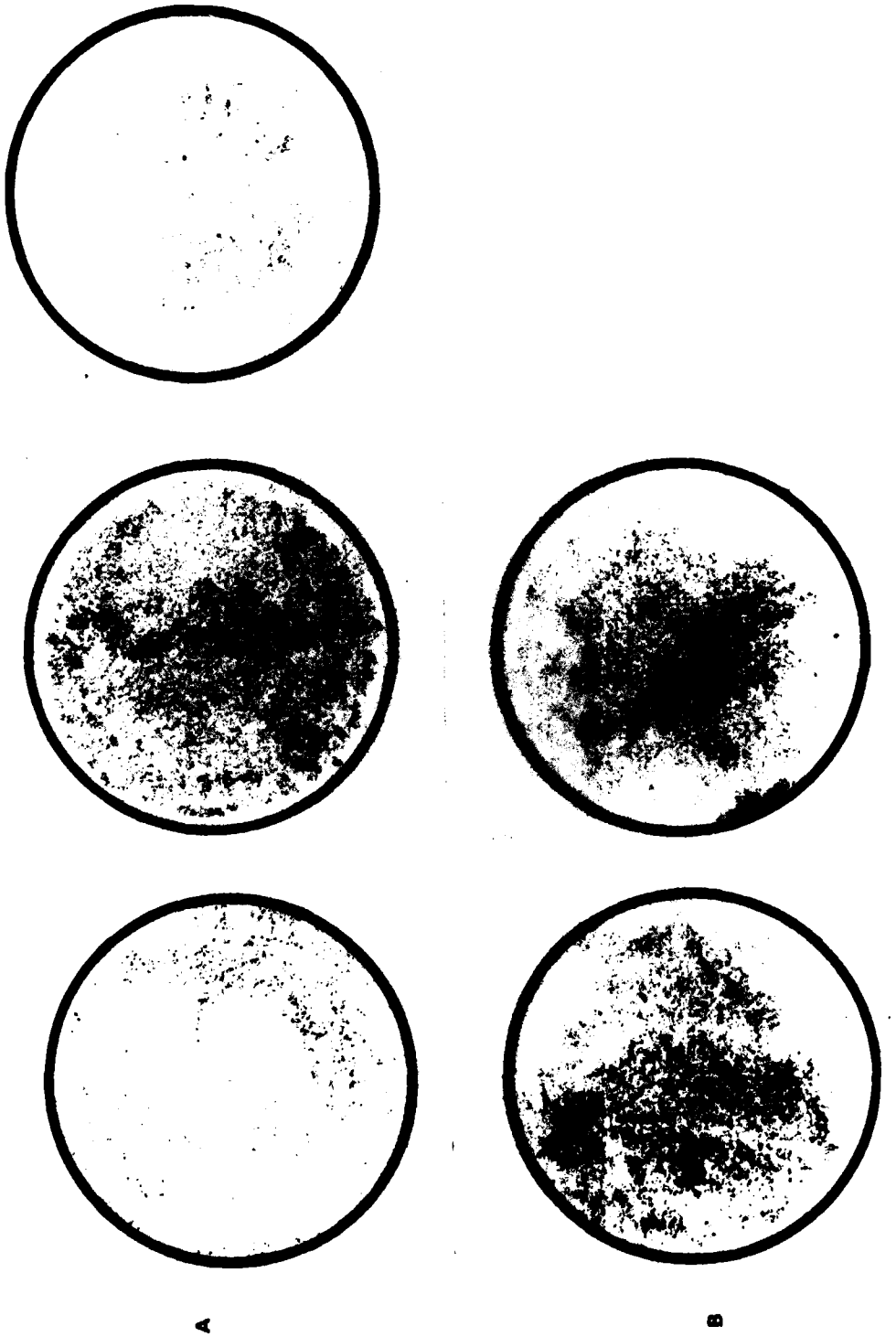


FIGURE 10 FILM RECOVERED FROM A. VRA-23 (P_w = 0.59 GPa) B. ALTU-16 (P_w = 0.46 GPa)

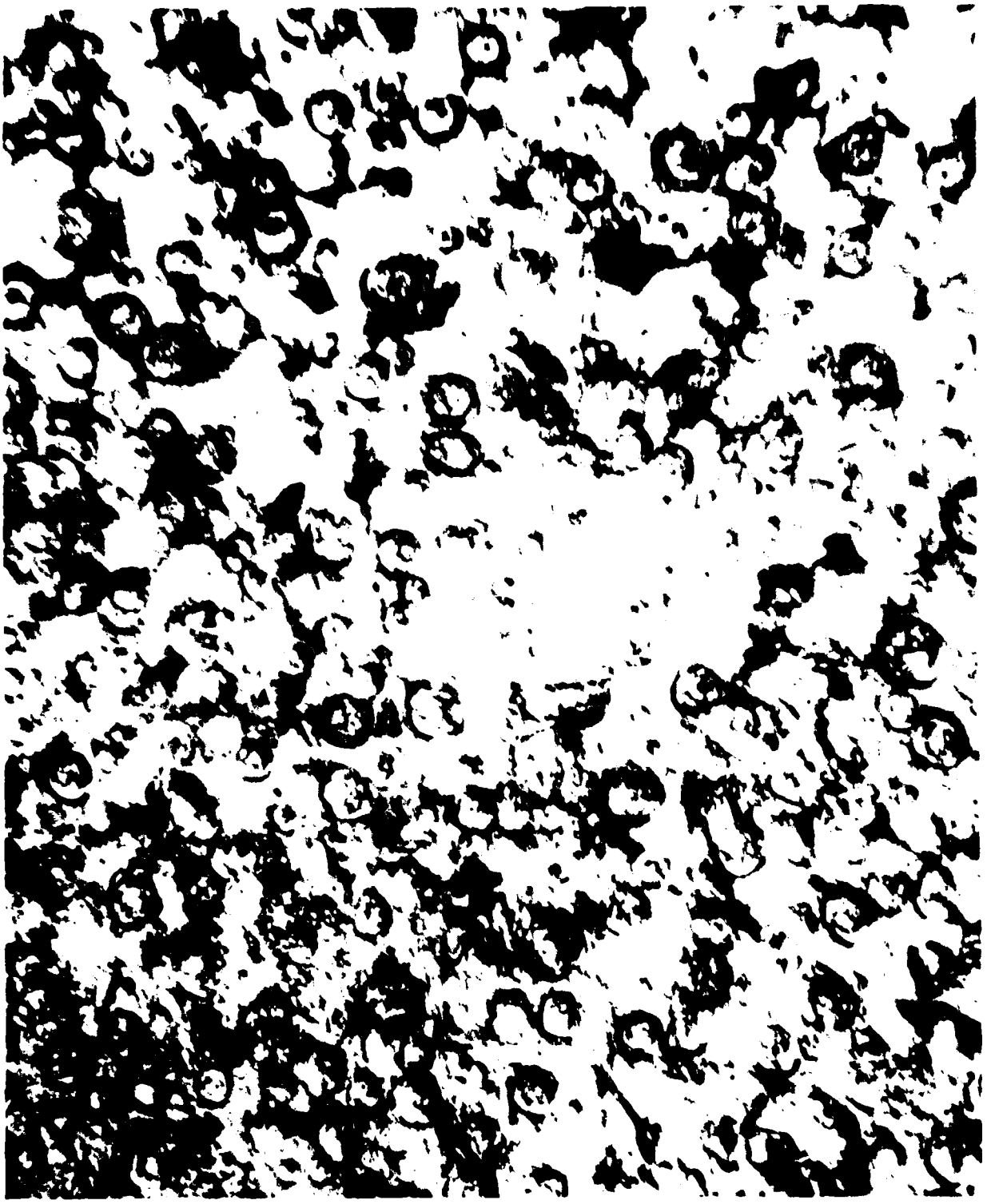


FIGURE 11 PHOTOMICROGRAPHIC ENLARGEMENT (120X) SHOWING CRATER PATTERN WITH CHARRED RIM PRODUCED BY FRACTURE OF GLASS BEADS IN PBXN-106 SIMULANT

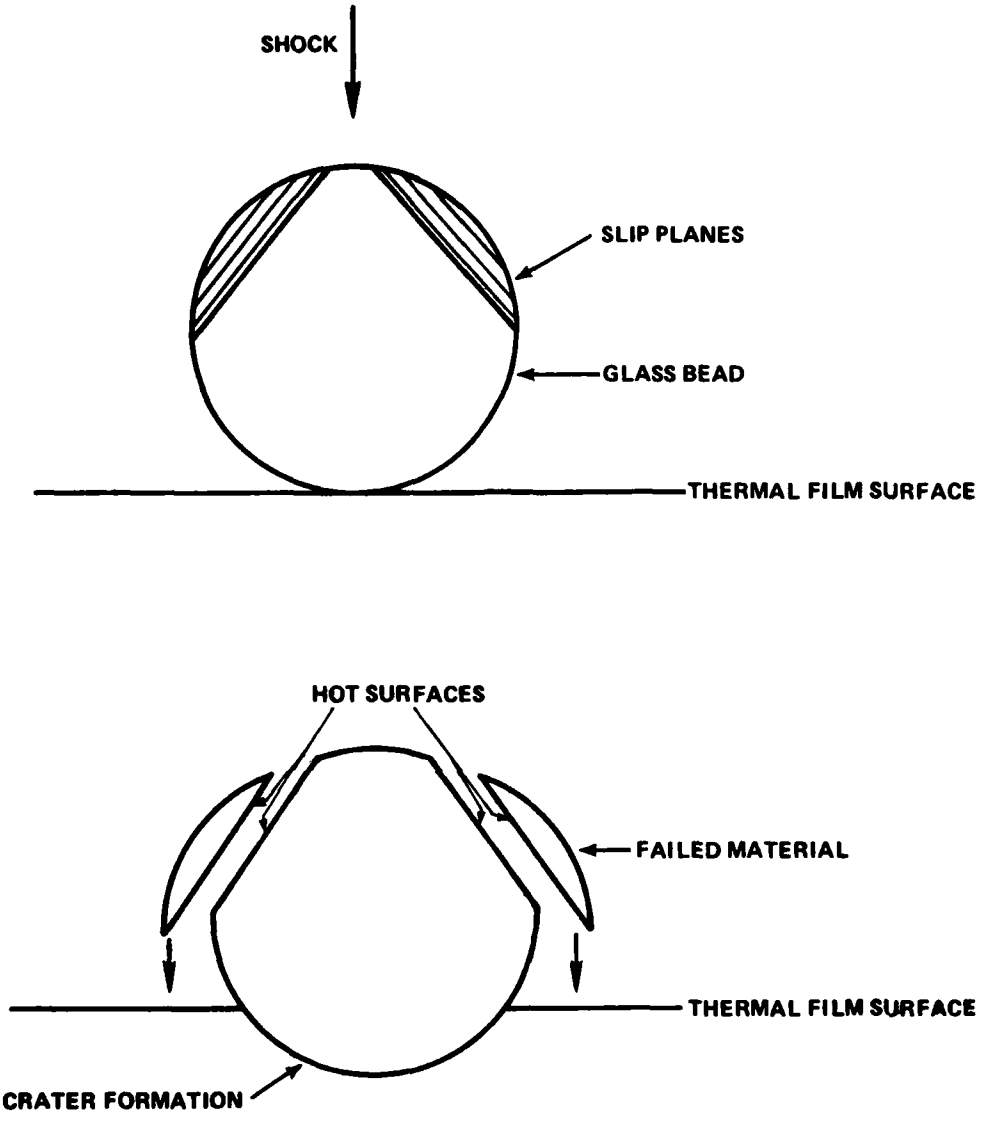


FIGURE 12 MODEL OF CRATER FORMATION WITH DEPOSITION OF HOT MATERIAL ON RIM

REFERENCES

1. Coffey, S., Elban, W., and Jacobs, S., Proceedings of the 16th JANNAF Combustion Conf. Monterey, CA, 1979.

2. Napadinsky, H., "Development of Methods for Predicting the Response of Explosive Material to Impact," Contract No. AF29 (601)2133, Report No. AFSWCTR-61-8, 1961.

3. Rice, M., McQueen, R., and Walsh, J., "Compression of Solids by Strong Shock Waves," Solid State Physics 6 1, Academic Press, NY, 1958.

4. Liddiard, T., "The Initiation of Burning in High Explosives and Propellants," Proc. of Fourth Int. Symposium on Detonation, 478 (ONR-1965).

5. Frankel, M., Liddiard, T., and Forbes, J., "Low Level Shock Reaction Thresholds in High Explosives and Propellants," to be published.

DISTRIBUTION

	Copies
Chief of Naval Material (MAT-08T222) Navy Department Washington, DC 20360	1
Director Office of the Secretary of Defense Defense Advance Research Projects Agency Washington, DC 20301	1
Director Defense Technical Information Center Cameron Station Alexandria, VA 22314	12
Commander Naval Research Laboratory Attn: Technical Library Washington, DC 20390	1
Director Lawrence Livermore Laboratory Attn: M. Finger J. Kury Technical Library University of California Livermore, CA 94550	 1 1 1
Director Los Alamos Scientific Laboratory Attn: J. Shaner B. Craig L. Hatler H. Flaugh Technical Library Los Alamos, NM 87544	 1 1 1 1

Commander
Naval Sea Systems Command
Attn: SEA-03B 1
SEA-033 (W. W. Blaine) 1
SEA-003 1
SEA-04H (Daugherty) 1
SEA-06D 1
SEA-09G32 2
SEA-62B 1
SEA-62R 1
SEA-62R32 1
SEA-64E (*Beauregard*) 1
Washington, DC 20362

Commander
Naval Air Systems Command
Attn: AIR-350 (E. M. Fisher) 1
AIR-350D (H. Benefiel) 1
AIR-350F (R. J. Wasnewski) 1
AIR-5323C 1
AIR-54131 1
AIR-950D (Technical Library) 1
Department of the Navy
Washington, DC 20361

Director
Strategic Systems Project Office (PM-1)
Attn: SP-273 (R. M. Kinert) 1
SP-27311 (E. L. Throckmorton Jr.) 1
Department of the Navy
Washington DC 20376

Chief of Naval Research
Office of Naval Research
Attn: ONR-741 (Technical Library) 1
ONR-473 (J. H. Satkowski) 1
ONR-473 (R. S. Miller) 1
Arlington, VA 2217

Commanding Officer
Naval Ordnance Station
Attn: Research and Development Department 1
DL (G. B. Stevenson) 1
Technical Library 1
Indian Head, MD 20640

Director
Sandia Laboratories
Attn: Technical Library 1
P. O. Box 5800
Albuquerque, NM 87115

Director
Johns-Hopkins Applied Physics Laboratory
Attn: S. Koslov 1
Technical Library 1
Johns-Hopkins Road
Laurel, MD 20810

Goddard Space Flight Center, NASA
Attn: Technical Library 1
Glenn Dale Road
Greenbelt, MD 20771

Commanding Officer
U. S. Army Armament Research and Development Command
Attn: R. Walker 1
N. Slagg 1
P. Marenkas 1
Technical Library 1
Dover, NJ 07801

Commanding Officer
Army Ballistic Research Laboratory
Attn: P. Howe 1
Technical Library 1
Aberdeen, MD 21005

Director
Air Force Office of Scientific Research
Attn: Library 1
Col. H. Bryan 1
E. Walsh 1
Bolling Air Force Base
Building 410
Washington, DC 20332

Commander
Air Force Armament Development and Test Center
Attn: Technical Library 1
L. Elkins 1
C. McCulloch 1
Eglin Air Force Base, FL 32542

F. J. Seiler Research Laboratory
Attn: Technical Library 1
U. S. Air Force Academy
Colorado Springs, CO 80840

Commander
Naval Weapons Center
Attn: L. Rothstein 1
Yorktown, VA 23491

Commander
Harry Diamond Laboratory
Attn: Technical Library 1
Silver Spring, MD 20901

Commander Naval Weapons Center
Attn: A. Adicoff 1
A. Addison 1
T. Joyner 1
D. B. Amster 1
D. Mallory 1
G. Greene 1
Sewell 1
Technical Library 1
China Lake, CA 93555

Library of Congress
Attn: Gift and Exchange Division 4
Washington, DC 20540

New Mexico Institute of Mining Technology
Attn: TERA (M. L. Kempton) 1
Socorro, NM 87801

Hercules Inc.
Attn: Technical Library 1
Allegany Ballistics Laboratory
P. O. Box 210
Comberland, MD 21502

Commanding Officer
Naval Ammunition Depot
Crane, IN 47522 1

H. S. Napadensky
ITT Research Institute
10 W. 35th St.
Chicago, IL 60616 1

NDW-NSWC(W)-5605/1 (Rev. 5-78)

TO AID IN UPDATING THE DISTRIBUTION LIST FOR NAVAL SURFACE WEAPONS CENTER, WHITE OAK TECHNICAL REPORTS PLEASE COMPLETE THE FORM BELOW:

TO ALL HOLDERS OF NSWC/TR 79-281
by Thomas P. Liddiard, Code R13

DO NOT RETURN THIS FORM IF ALL INFORMATION IS CURRENT

A. FACILITY NAME AND ADDRESS *(OLD) (Show Zip Code)*

NEW ADDRESS *(Show Zip Code)*

B. ATTENTION LINE ADDRESSES:

C.

☐ **REMOVE THIS FACILITY FROM THE DISTRIBUTION LIST FOR TECHNICAL REPORTS ON THIS SUBJECT.**

D.
NUMBER OF COPIES DESIRED _____

GPO 800-904

DEPARTMENT OF THE NAVY
NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MD. 20910

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY
DOD 316

COMMANDER
NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MARYLAND 20910

ATTENTION: CODE R13